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Attributes of success in a challenging information processing environment

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THESIS

ATTRIBUTES OF SUCCESS IN A CHALLENGING INFORMATION PROCESSING ENVIRONMENT

by

David E. Faherty III

September 2007

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13. ABSTRACT (maximum 200 words)

By using graph-theoretic techniques to compare the information processing behaviors of three groups of mid-level working professionals as each undertakes a series of four complex, interdependent, computer-mediated decision-making exercises, this thesis explores 1) the relationship between network centrality and individual performance and 2) the relationship between network density and group performance. The results of this exploration, though mostly inconclusive, call into question both intuition and social network analysis literature. It is predicted that centrality in a network correlates positively with high performance among individuals, but statistical analysis of data collected during controlled experimentation reveal an almost negligible relationship. It is also hypothesized that high density groups outperform low density groups, but density and performance are found to correlate in exactly the opposite direction: as density increases, group performance decreases.

As an explanation, this thesis proposes that as network density increases actors require more time to process and respond to incoming information. In as much as central actors possess a greater number of edges (i.e., communication linkages to others), this thesis also argues that centrality in a network has costs, as well as benefits. Further experimentation is needed to test the validity of these conjectures and bring better understanding to Organization Theory, Social Network Analysis, and Information Processing networks.

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ATTRIBUTES OF SUCCESS IN A CHALLENGING INFORMATION PROCESSING ENVIRONMENT

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I. INTRODUCTION

Although many studies have been undertaken which study the performance of organizations, the virtues of a computer mediated experiment—increased control over data collection, increased volume of data collected, and increased computational power—enable the researcher in certain instances to make more confident assertions about organizational behavior than he otherwise is enabled using different techniques. In order to explore the dynamic transactions that occur within an organization, beyond its macro level design features, over the years social network analysis scholars have developed powerful graph-theoretic techniques which allow researchers, in one sense, to look under the hood of an organization and observe its inner workings. This thesis uses these techniques to explore 1) the relationship between network centrality and individual performance and 2) the relationship between network density and group performance.

A. PURPOSE AND MOTIVATION

In as much as one encounters organizations unsuited to their information processing requirements, studies of how these organizations adapt to their adverse environment has the potential to highlight what, if any, differences in communications processing patterns can be deemed beneficial. A great many organizations today, transitioning from the Industrial Age into the Information Age, possess structures that are unsuited to their environment. As these organizations labor to change the “anti-sharing, anticollaborative" behaviors typical of hierarchies and bureaucracies, society continues to demand that they function in their weakened state whether in industry, government, or defense.[1] It has been argued that the mechanistic form of organization that evolved from and so pervaded the Industrial Age will be unable to handle the challenges of the future.[2]

In some cases these organizations will meet with success, as certain subunits adapt to changing information processing requirements. The failures of other organizations, however, will result in the need for further reevaluation and subsequent restructuring. It is therefore important to obtain some understanding of the characteristics of a successful, yet, disadvantaged organization as it struggles with a demanding environment to which it is unsuited. This thesis is an attempt to understand these attributes, though from a laboratory based computer mediated exercise, rather than first hand field studies and observations. Whereas organizations sometimes operate in information processing environments to which they are not suited, this thesis seeks to uncover through the use of graph-theoretic techniques, what social network analysis measures correlate with high performance.

B. METHOD

From the 10th of January until the 15th of February, 2007, a series of experiments took place in the Information

[1] David S. Alberts and Richard E. Hayes, *Power to the Edge* (Command and Control Research Project, 2003), 73.

[2] Simon R. Atkinson and James Moffat, *The Agile Organization* (Command and Control Research Project, 2005), 158-159.

Sciences Department of the Naval Postgraduate School that examined the performance of two distinct types of organizations: the Hierarchy and the Edge. The experiment details are summarized in Leweling and Nissen (2007). Although the hypotheses tested in this thesis were formulated after the design and execution of the experiment, the data collected were so rich as to enable exploration into topics not originally conceived as part of the experiment.

C. ANALYSIS

For this thesis, the author coded data from the log files generated during the ELICIT experiment into time demarcated adjacency matrices which are then evaluated with the *Organizational Risk Analyzer* (ORA), a social network analysis software application developed at Carnegie Mellon University. By means of the software these data are converted into reliable measures of centrality and density, the independent variables analyzed in this thesis. Performance, in terms of time and accuracy, are the dependent variables of this thesis. Finally, the independent and dependent variables are checked for correlations.

D. ORGANIZATION OF THESIS

The following chapter presents a succinct survey of relevant Organizational Theory literature that will begin with Mintzberg (1983) and terminate with Nissen, drawing lightly upon Burns and Stalker (1961) and Lawrence and Lorsch (1967). Chapter II concludes with the statement of hypotheses. Chapter III begins with an introduction to the

ELICIT experiment that provides a description of its environment, purpose, and organization; it is an explanation of how ELICIT attempts to operationalize and compare the Hierarchy and Edge Organizations. This chapter also delineates the measures used to determine an agent’s success within a complex and interdependent information processing environment. Chapter IV details the statistical results of the research with respect to the hypotheses under investigation. Chapter V summarizes these results and offers an attempt to bridge the divide between reality and the results of this computer mediated decision making exercise, explaining the real world applicability of its conclusions. The thesis ends with a brief summary and suggestions for future research opportunities.

II. LITERATURE REVIEW

In order to ground the research and analysis, this chapter begins with a brief review of organizational theory, and in particular, information processing as a framework for viewing organizations. We also provide fixed definitions for Edge and Hierarchy forms to permit disciplined exploration of these forms.

A. ORGANIZATIONAL THEORY

Any study of organization theory requires that the one be familiar with the major points of Henry Mintzberg's seminal work, *Structures in Fives: Designing Effective Organizations*. This book represents a basis for the present investigation.

1. The Five Coordinating Mechanisms

Mintzberg (1983) posits that five ways exist in which organizations can coordinate their work: 1) mutual adjustment, 2) direct supervision, 3) standardization of work processes, 4) standardization of outputs, and 5) standardization of skills. Mutual adjustment accomplishes its end by means of informal communication that takes place between "doers." Mintzberg (1983) states that although mutual adjustment is used in the simplest of organizations, "paradoxically, it is also used in the most complicated."[3] The challenges facing an organization in the most complex of environments are often unknown or vaguely understood,

[3] Henry Mintzberg, *Structures in Fives: Designing Effective Organizations* (Upper Saddle River, New Jersey: Prentice Hall, 1983), 4.

requiring that people within the organization “adapt along their uncharted route.”[4] A slightly larger organization requires a different type of coordinating mechanism: direct supervision. In this case, one individual is placed in charge of several others, and spends his time giving instructions to his subordinates and monitoring their actions.

Work can further be coordinated by standardization. Work processes are standardized when an organization provides its laborers with a clear set of instructions for them to follow. Fast food restaurants are an example, where employees fill food orders in an assembly line fashion and are successful to the extent that they do not deviate from the thorough set of instructions provided by management. When an organization produces many different goods and services consolidation is achieved by standardization of outputs. For multinational corporations the standardization is focused on growth in earnings.

Finally, work can be coordinated by means of standardization of skills and knowledge. In the case of universities, for example, professors teaching in a classroom possess the training and knowledge necessary to educate. Mintzberg (1983) notes that, “As an organization’s work becomes more complicated, the favored means of coordination seems to shift from mutual adjustment to direct supervision to standardization… finally reverting back to mutual adjustment.”[5]

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[4] Mintzberg, *Structures in Fives*, 4.

[5] Mintzberg, *Structures in Fives*, 4-7.

2. The Five Elements of Organizations

In Mintzberg’s model, the five elements of an organization are: 1) operating core, 2) strategic apex, 3) middle line, 4) technostructure, and 5) support staff.

Relating to the production of products and services, the operating core is concerned most directly with the basic work of the organization. The operators have four primary functions: to 1) secure inputs, 2) transform inputs to outputs, 3) distribute outputs, and 4) provide direct support to the input, output, and transformation functions.[6]

Although the operating core is the heart of every organization, in order to function effectively organizations require an administrative apparatus as well. The head of the administrative component is the strategic apex, which ensures that the organization carry out its mission in an effective way, and fulfill the desires of those who control or have power in the organization, such as its stockholders, employees, or donors. Concurrently, the strategic apex has three sets of duties: 1) to the extent that the organization relies on direct supervision, they allocate resources, issue orders, authorize major decisions, resolve conflicts etcetera, 2) manage the organization’s relation with the outside environment, and 3) develop strategy, the mediating force between the organization and its environment.[7] Connecting the strategic apex with the operating core is the middle line. When an organization relies heavily on direct

[6] Mintzberg, *Structures in Fives*, 12.

[7] Mintzberg, *Structures in Fives*, 13.

supervision, the middle line tends to grow quite large, creating an organizational hierarchy.

On the other hand, the technostructure formulates certain methods of standardization for the organization. It is composed of analysts who are removed from the work flow, but may design it, or train people for it. Finally, the support staff exists to provide services to the members of an organization that are not involved with operating work flow, for instance: payroll and janitorial services.[8]

3. The Five Typologies of Organizations

In Mintzberg’s model, organizations possess one of five distinct typologies: 1) Simple Structure, 2) Machine Bureaucracy, 3) Professional Bureaucracy, 4) Divisional Form, and 5) Adhocracy.

As the name suggests, the Simple Structure is the least elaborate of the five forms of organization. Generally, it has little formalized behavior and few support staff, lacks a technostructure and a strict division of labor, and has a small managerial hierarchy. It is the most organic of forms.[9]

Most clearly the object of this thesis, the Machine Bureaucracy is characterized as highly formalized, highly specialized, and hierarchical. Because this form of organization predominately relies on formalization of processes for coordination, the technostructure becomes essential to the organization’s successful operation.[10]

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[8] Mintzberg, *Structures in Fives*, 15-16.

[9] Mintzberg, *Structures in Fives*, 157-158.

[10] Mintzberg, *Structures in Fives*, 164-165.

During the Industrial Era, the Machine Bureaucracy emerged as the organizational form most well suited to the environment of that time.[11] Its structure repeatedly demonstrated the ability to mass produce goods, run governments, and fight wars.

The third typology Mintzberg (1983) considers is the Professional Bureaucracy which relies heavily upon the training and indoctrination necessary to coordinate by means of standardization of skills. Doctors, teachers, and accountants in effect learn what to expect from their counterparts within the Professional Bureaucracy.[12]

The key element of the Divisional Form of organization is the middle line. Each division operates with near autonomy within its highly circumscribed area, using standardization of outputs to achieve coordination.

The last typology Mintzberg (1983) addresses is the Adhocracy, which, similar to the Simple Structure, achieves coordination by mutual adjustment. He considers this form to be highly organic with little formalization, agile in complex, dynamic environments, and the "least reverent for classical principles of management, especially unity of command."[13]

4. The Eight Design Factors

Mintzberg (1983) also includes a description of eight design factors necessary to the workings of any organization. They are: 1) job specialization, 2) behavioral

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[11] Alberts and Hayes, *Power to the Edge*, 37-51.

[12] Mintzberg, *Structures in Fives*, 190.

[13] Mintzberg, *Structures in Fives*, 253-254.

formalization, 3) training and indoctrination, 4) unit grouping, 5) unit size, 6) planning and control systems, 7) liaison services, and 8) decentralization.

Job specialization possess both a horizontal component—how many different types of tasks a worker accomplishes—and a vertical component—how much control the work has over the "how" and "why" of his tasks. Organizations formalize behavior in three ways: by position, by work flow, and by rules. Training and indoctrination refer the process by which organizations impart job related skills and organizational norms.

Unit grouping provides four important effects to an organization: it establishes a system of command supervision among positions and units, requires positions and units to share common resources, creates a common measure of performance, and encourages mutual adjustment. Unit size affects the coordination mechanism most suited to an organization.

Liaison services and planning and performance controls "grease the wheels of mutual adjustment."[14] Lastly, when the power to make decisions is widely dispersed throughout an organization, the organization is said to be decentralized.[15]

B. INFORMATION PROCESSING MODEL

In a step away from Mintzberg (1983) and the number five, Tushman and Nadler (1978) choose instead to view organizations as information processing systems. The

[14] Mintzberg, *Structures in Fives*, 73.

information processing model is based on assumptions derived from well accepted organization theory literature. First, Tushman and Nadler (1978) assert that organizations are open social systems which must deal with work-related uncertainty. Dependent on inputs from the environment in which they are situated, organizations may have to process uncertainties that arise from sources beyond their control. Additionally, uncertainties emerge from within an organization as a result of a multitude of human factors. In order to cope with both external and internal sources of uncertainty, organizations must develop information processing mechanisms which translate multifarious forms of data into timely, accurate, concise, and relevant information.

With this in mind, Tushman and Nadler (1978) affirm that it is beneficial to view organizations as information processing systems. Finally, they claim that organizations are composed of subunits, each having to deal with a varying degree of uncertainty relative to the its position within the organization’s information processing structure and the external environment.[16] From these assumptions, Tushman and Nadler (1978) derive a series of five propositions, the last four of which are salient to this thesis:

1. Proposition 1

The tasks of organizational subunits vary in their degree of uncertainty.

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[15] Mintzberg, *Structures in Fives*, 25-95.

[16] Tushman and Nadler, “Information Processing as an Integrating Concept in Organizational,*” The Academy of Management Review* (July, 1978), 615-616.

A subunit's degree of uncertainty and therefore of information processing requirements results from subunit task characteristics, subunit task environment, and inter-unit task interdependence.[17]

2. Proposition 2

As work related uncertainty increase, so does the need for increased amounts of information, and thus the need for information processing capacity.

When subunits face little uncertainty, they need only pass on the barest of information to their superiors and other subunits in the organization. However, when subunits face a high degree of uncertainty, they must transmit to the organization a correspondingly high degree of information. This additional information requires that the organization as a whole is capable of processing more information.[18]

3. Proposition 3

Different organizational structures have different capacities for effective information processing.

While certain stable environments may be conducive to mechanistic organizational forms, organizational theory literature generally attributes a higher degree of information processing capacity to more organic forms of organization. The literature indicates that more connected forms of organizations are better able to handle uncertainty, permitting individuals to mutually adjust to solve problems and error correct. Despite being better able

[17] Tushman and Nadler, *The Academy of Management Review*, 615.

[18] Tushman and Nadler, *The Academy of Management Review*, 616-617.

to handle higher levels of information flow, organic organization structures expend more time and energy to achieve their solutions. Thus, the choice of structure must balance need with cost.[19]

4. Proposition 4

Organizations will be more effective when there is a match between information processing requirements facing the organization and information processing capacity of the organization.

In the case of an organization with not enough information processing capacity for its environment, Tushman and Nadler (1978) expect performance to be degraded. Likewise, if an organization over invests in information processing capacity, they assert that performance will be less than optimal. Only when structure matches capacity will there be a match that is both efficient and optimal.[20] These assertions are diagramed in Table 1.

[19] Tushman and Nadler, *The Academy of Management Review*, 617-618.

[20] Tushman and Nadler, *The Academy of Management Review*, 619-620.

Information Processing Requirements	Information Processing Capacity	
	High	**Low**
Extensive	Match A	Mismatch B
Minimal	Mismatch C	Match D

Table 1. Relationships Between Information Processing Capacity and Information Processing requirements. From Tushman and Nadler [21]

5. Proposition 5

If organizations face different conditions over time, more effective units will adapt their structures to meet the changed information processing requirements.

Existing in a dynamic, evolving world, organizations will not always face the same environment in which they were formed. As their environment changes, so too does the need for information processing capacity, and therefore organizations must adapt their information processing structure in order to remain fit.

21 From Tushman and Nadler, The Academy of Management Review, 619.

C. ORGANIZATION PERFORMANCE AND ENVIRONMENTAL CHANGE

Although macro level organizational design factors certainly influence group performance, Pearce and David (1983) argue that they do so indirectly—through information flow—and that group level characteristics serve to moderate performance.[22] Unearthing these group level characteristics is possible through use of social network analysis to study information exchange and influence relationships, an analytical technique specifically recommended by Pearce and David (1983). Social network properties have been compared to measures of performance, and some organization theory scholars have suggested that that, among others, the following group structural properties positively impact performance: 1) high centrality, 2) few coalitions, 3) few isolates, 4) many stars, 5) many liaisons, 6) high connectedness, and 7) high reciprocity. Additionally, these properties are believed to negatively impact performance: 1) many coalitions, 2) many isolates, 3) few stars, 4) few liaisons, 5) low connectedness, and 6) low reciprocity.[23]

It is not clear at this time the extent to which today's organizations will confront a more complex information processing environment than the environment in which they developed. But clearly, the world is not static, and the increasing complexity noted by many scholars associated with "globalization, technology, hyper-competition, and, knowledge-based innovation" will force

22 John A. Pearce II and Fred R. David, "A Social Network Approach to Organizational Design-Performance," Academy of Management Review (July, 1983), 436.

23 Pearce and David, Academy of Management Review, 441.

ill-structured organizations into a more dynamic, unstable environment.[24] As the macro level design features hinder certain organizations as they attempt to meet the increasingly extensive information processing requirements of the future, one is still likely to find strong performance among groups and individuals defined by the aforementioned structural properties.

D. USING NETWORK ANALYSIS TO EXPLORE ORGANIZATIONS

Organizational theorists choose to deconstruct and analyze organizations in many ways, including in terms of structure and macro level design features. While this approach allows theorists to develop constructs concerning complexity, formalization, centralization, technology, and size, Fombrun and Tichy (1979) argue that such a perspective by itself is insufficient for capturing the dynamic realty of organizations.[25] With this in mind, social network analysis attempts to enrich a limited and static viewpoint by empirical measures of the behavior of individual actors within an organization. And yet, organizational theorists are unable to incorporate social network analysis without a debate concerning the nature of networks as they relate to organizations.

24 Tara A. Leweling and Mark E. Nissen, “Hypothesis Testing of Edge Organizations: Laboratory Experimentation using the ELICIT Multiplayer Intelligence Game” 12th International Command and Control Research and Technology Symposium: Adapting C2 to the 21st Century (Newport, RI June, 2007), 2.

25 Charles Fombrun and Noel Tichy, “Network Analysis in Organizational Settings,” Human Relations (1979), 926.

Some scholars, such as Podolny and Page (1991), Bovasso (1992), and van Alstyne (1997) view networks as a fundamentally new type of organization defined as:

> Any collection of actors ($N \geq 2$) that pursue repeated, enduring relations with one another and, at the same time, lack a legitimate organizational authority to arbitrate and resolve disputes that may arise during exchange.[26]

This view sees the network form of organization as an intermediate between hierarchies and markets, where spontaneously emerging informal links supersede the formal organizational chart.[27] In doing so, the network organization is better able to respond to the "contingencies created by changing markets, technology, and other facets of a chaotic business environment."[28]

In contrast, other scholars such as Tichy, Tushman, and Fombrun (1979), and Krackhardt and Carley (1992), view networks as something that resides within and between organizations. They also argue that network analysis tools should be used to explore organizations and their emergent structures and behavior patterns. In fact, some scholars even consider the network itself to be the true structure in an organization.[29] This perspective acknowledges that variations in the prescribed organizational form may alter

26 Joel M. Podolny and Karen Page, "Network Forms of Organization," Annual Review of Sociology (1998), 59.

27 Stephan P. Borgatti and Pacey C. Foster, "The Network Paradigm in Organizational Research: A Review and Typology," Journal of Management (2003), 995.

28 Gregory Bovasso, "A Structural Analysis of the Formation of a Network Organization," Group Organization Management (1992), 87.

29 Ronald S. Burt, Towards a Structural Theory of Action: Network Models of Social Structure, Perception, and Action (New York: Academic Press, 1982).

the characteristics of the emergent network, but insists that other factors besides the formal structure critically impact the evolution of the network.[30]

E. STATEMENT OF HYPOTHESES

Pearce and David (1983) assert that social network measures can be used to test the performance of emergent structures that describe alternative interaction patterns among individuals in a group.[31] The following hypotheses test the performance of the Hierarchy in complex information processing environment, seeking to uncover the attributes of performance related to individuals and groups. The information processing environment created by the ELICIT experiment is not the best match for the Hierarchy. As a result a mismatch occurs identical to mismatch B, identified by Tushman and Nadler (1978) in Figure 1, where the Hierarchy’s information processing capacity is low, while the information processing requirements are extensive. Yet, during the ELICIT experiment, the Hierarchy and its actors still meet with success, albeit to a lesser degree than do the Edge and its actors. It appears that, just as Pearce and David (1983) assert, the macro level design features of ELICIT’s Hierarchy configuration are being moderated by group level characteristics. Again, the subsequent hypotheses test for the relevance of these characteristics within ELICIT’s Hierarchy configuration.

30 Fombrun and Tichy, Human Relations, 929.

31 Pearce and David, Academy of Management Review, 437.

1. Individual-Level Predictions

The positions of high performing individuals are different from the positions of low performing individuals within a group's information processing structure.

Every session of the ELICIT experiment results in the formation of a web of communication between actors. Each unique network represents only one outcome out of many possible outcomes. Each actor within the network possesses a set of nodal characteristics that describe his relationships with other actors and the network itself. The figure below is a representation of the network generated by ELICIT during one experimental session. Visually, it is immediately apparent that individual actors—represented by points—have differing characteristics.

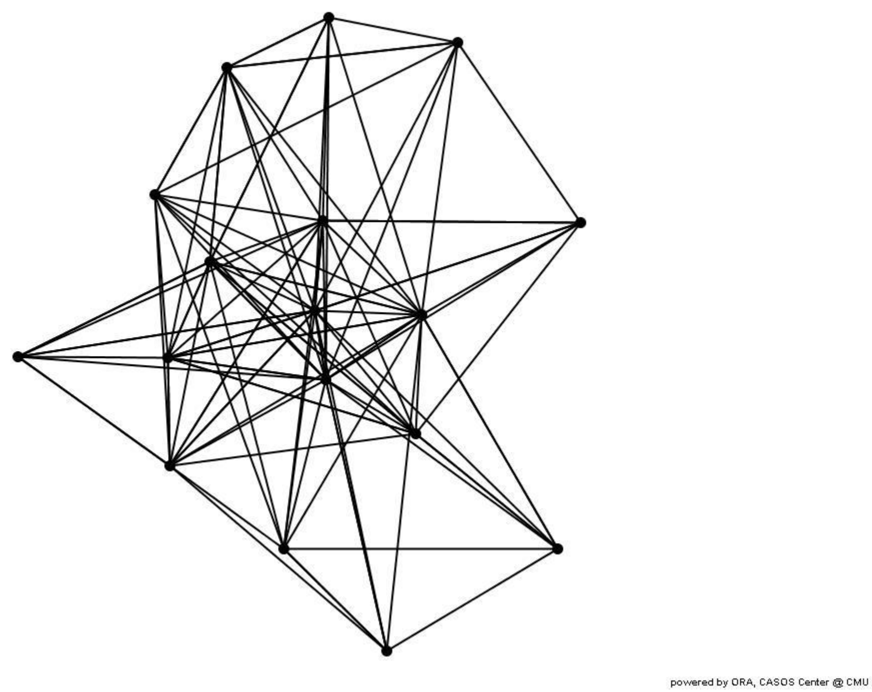

Figure 1. Meta Matrix from one experimental session.

a. H1.1: Degree Centrality

High performing individuals are more likely to be found in the center of an organization's communication network.

Centrality is a measure of the extent to which an actor is central to a network.[32] Wasserman and Faust (1994) assert that an actor with a large degree centrality is recognized as a major channel of relational information and a crucial cog in the network.[33] There are a variety of different centrality measures; the one chosen for this hypothesis is degree centrality. ORA defines total degree centrality as the normalized in-plus out-degree of an actor.

b. H1.2: Betweenness Centrality

A high degree of an individual's betweenness correlates positively with high performance.

Betweenness is the "extent to which an actor mediates, or falls between any other two actors on the shortest path between those actors."[34] An actor with a high degree of betweenness is considered to derive power by "controlling or brokering the flow of information."[35] Friedkin (1991) states that betweenness indicates increased interpersonal influence.[36]

32 Peter R. Monge and Noshir S. Contractor, Theories of Communication Networks (Oxford: Oxford University Press, 2003), 32.

33 Stanley Wasserman and Katherine Faust, Social Network Analysis: Methods and Applications (New York: Cambridge University Press, 1994), 179.

34 Monge and Contractor, Theories of Communication Networks, 32.

35 Monge and Contractor, Theories of Communication Networks, 38.

36 N.E. Friedkin, "Theoretical Foundations for Centrality Measures," American Journal of Sociology (1991), 1478-1504.

c. H1.3: Closeness Centrality

A high degree of an individual's closeness correlates positively with high performance

Closeness is the "extent to which an actor is close to, or can easily reach all the other actors in the network."[37] An actor may be close to other actors by possessing many links to other actors, or by possessing links to actors who themselves have many links to other actors. Monge and Contractor state that an actor's closeness measures his ability to receive information directly or indirectly "through the grapevine."[38] Beauchamp (1965) relates that actors who are central with regard to closeness can be very productive in communicating information to other actors.[39]

2. Team-Level Predictions

High performing groups exhibit characteristic communication processing patterns different from low performing groups.

Where as the First Substantive Hypothesis deals with individual actors and their corresponding attributes, this hypothesis examines group level characteristic, density.

a. H2.1: Group Density vs. Speed

Higher density networks submit answers in less time than lower density networks.

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37 Monge and Contractor, Theories of Communication Networks, 32.

38 Monge and Contractor, Theories of Communication Networks, 39.

39 M.A. Beauchamp, "An Improved Index of Centrality," Behavioral Science (1965), 161-163.

The density of a network increases as number of connections between actors increases. That is to say, the density of the network is the ratio of total links to possible links in a network.[40] The assumption behind this hypothesis is that, in a denser network, more relevant information comes to actors in less time, which results in an overall decrease in the time necessary to make decisions. Previous studies of density find it to be a measure of group cohesion[41] and "knittedness."[42]

b. H2.2: Group Density vs. Accuracy

Higher density networks submit more accurate answers than lower density networks.

Because higher density networks possess more avenues through which information is passed, this hypothesis is based on the assumption that on average higher density groups are empowered to make more accurate decisions.

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40 Monge and Contractor, Theories of Communication Networks, 44.

41 P.M. Blau, Inequality and Heterogeneity, (New York: Free Press, 1977).

42 J.A. Barnes, "Graph Theory and Social Network: A Technical Comment on connectedness and connectivity," Sociology (1969), 215-232.

III. METHODOLOGY

The following description of method outlines the means used to collect the data for this thesis and the method by which it is analyzed. A brief description of the ELICIT experiment and its measures enables the reader to better understand the nature of the data and the validity of the results. Additionally, the reader is made aware of the techniques used to transmute the raw data generated during the ELICIT experiment into the form required for analysis with social network analysis software.

A. INTRODUCTION TO ELICIT

Originally, the ELICIT experiment was conceived to test and compare the performance of two organizational forms, the Edge and the Hierarchy as described above in the Literature Review. Preliminary results are available in Leweling & Nissen 2007.[43] The following description of the ELICIT experiment, its environment and measures, are based exclusively on this paper.

1. ELICIT Environment, Organization, and Purpose

Individuals participating in the ELICIT experiment are asked to identify the details of a fictitious terrorist plot, specifically: who, what, where, and when. In the

43 Tara A. Leweling and Mark E. Nissen offer the preliminary results and conclusions of this investigation in a paper entitled “Hypothesis Testing of Edge Organizations: Laboratory Experimentation using the ELICIT Multiplayer Intelligence Game” presented at the 12th International Command and Control Research and Technology Symposium: Adapting C2 to the 21st Century held in Newport, Rhode Island in June, 2007.

intelligence game, 68 informational clues called “factoids” are distributed throughout the group of 17 players over a period of ten minutes. Each player receives four factoids, two initially, another at five minutes, and the final factoid after ten minutes of game play. The set of factoids that each player receives may contain information relevant to the terrorist plot, but each set is arranged so that no player receives enough information to correctly identity the entire solution. Thus, collaboration becomes necessary among the group of players in order to solve the problem correctly. Presently, there are four versions of the game, which though structurally similar are each composed of a unique set of 68 factoids. More versions of the game can be created, but the process is time consuming and tedious.

The client application is loaded onto separate, networked computers providing each player with a set of five functions needed to play the game: 1) List, 2) Post, 3) Pull, 4) Share, and 5) Identify. The List function shows all of the factoids the player has received, either from the initial distribution, or from other players via the Share function. Post provides players with a common screen that displays a list of factoids visible to multiple players. A player takes factoids from his list and places them on one of the four different Post screens. Contrarily, a player uses Pull to take factoids from one of the common screens and add them to his list. As mentioned above, the solution to the terrorist plot contains four parts—who, what, where, and when—and so, the four Post screens contain information pertinent to each part of that solution. The game limits the sharing of information to two functions, of which Post is one and Share is the other; during the experiment, no verbal communication is permitted. In order to pass factoids to specific individuals, a player first selects the factoid to be sent and then chooses the desired recipient from a list of the 17 in-game pseudonyms. When a player decides that he possess the correct description of the terrorist plot, he uses the Identify function to enumerate the details, i.e., who, what, where, and when.

Throughout the game, the server application records and time stamps transaction data on text-file logs. Nearly every activity that takes place in the game is registered on these log files, including when, which, and to whom factoids are distributed, posted, pulled, viewed, and shared. The log files also record when and what each player identifies as his solution. Researchers then process these files in any number of ways in order to distill the information which they desire.[44] For this thesis the author coded data from the log files into time demarcated adjacency matrices which were then evaluated with the *Organizational Risk Analyzer* (ORA), a social network analysis software application developed at Carnegie Mellon University.[45]

2. Operationalizing the Edge and Hierarchy

To test and compare the performance of the Hierarchy and the Edge experimental environments are created with the ELICIT software that are modeled after both organizational forms. Firstly, regardless of the configuration, a subject is assigned to one of four groups. Again, the groups

44 Leweling and Nissen, 12th ICCRTS, 5.

correspond with a part of the Identify function; there is a "who" group, a "what" group, and so on. While playing in the Edge configuration, subjects are allowed to interact with all of the post-pull common screens. Specifically, a member of the "who" group, in addition to his own screen, can Pull from and Post to the "what" screen, the "where" screen, and the "when" screen. The situation while in the Hierarchy configuration is dramatically different. To begin with, there is an overall group leader (i.e. labeled "1") who is responsible for the intelligence organization as whole. Reporting directly to him are four functional leaders (i.e. labeled "2," "6," "10," and "14") each of whom is in charge of the three analysts assigned to his group. The interactions between these groups is limited in as much as a member of the "who" group, for instance, is only able to Pull from and Post to the "who" common screen. Likewise, but for the over all group leader who has access to all four screens, every other player has truncated access to the common screens. However, players are still able to pass factoids to each other via the Share function.[46]

45 Kathleen M. Carley, ORA: the Organizational Risk Analyzer (Pittsburgh, Pennsylvania: Carnegie Mellon University, School of Computer Science, Institute for Software Research International, Center for Computational Analysis of Social and Organizational Systems, 2007).

46 Leweling and Nissen, 12th ICCRTS, 8.

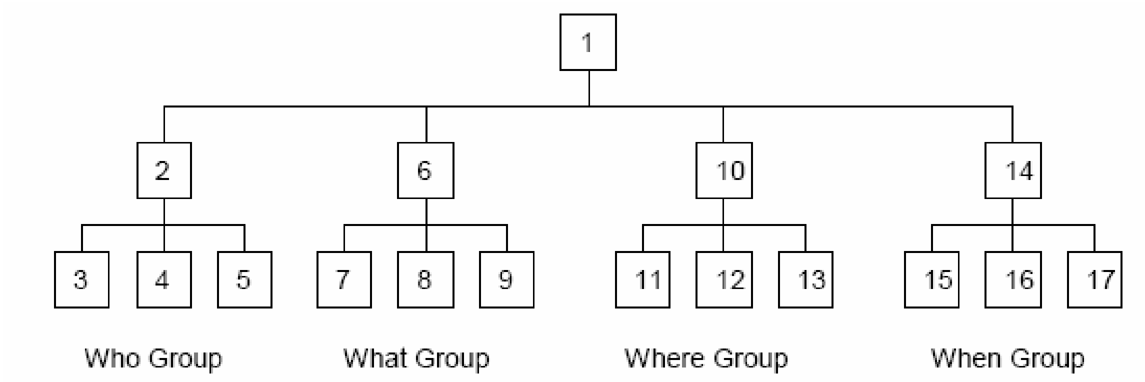

Figure 2. Hierarchy Organization from Leweling and Nissen

The ELICIT experiments employ an additional means of communication for players which for the purposes of this thesis has been treated as another type of sharing. Players share Postcards with each other several times throughout the game. Players pick to whom to send their Postcards, but their options are limited while in the Hierarchy configuration; a subject is only permitted to share postcards with members of his own group, while functional leaders are allowed to share postcards with the overall leader, and the overall leader can share them with anyone. While factoids represent the sharing of information, Postcards provide a snapshot of how a player understands the information at a certain moment in time. That is to say, to share a Postcard is to convey one's knowledge.[47] Further information about the use of Postcards in the ELICIT experiments and the results of the hypotheses associated with them can be found in aforementioned paper by Leweling and Nissen.

47 Leweling and Nissen, 12th ICCRTS, 10-12.

B. FROM LOG FILES TO INDEPENDENT VARIABLES

In all, eight of the sixteen log files generated during the ELICIT experiment are analyzed in this thesis, specifically the ones having to due with the hierarchy configuration. As mentioned above, each log file notes the time and type of interaction that occurs between subjects. These events are displayed in a text document where on each line is recorded the specifics of the event: who, what, and when. Experimental sessions last approximately one hour; by the end of a session the log file generated is approximately one hundred and fifty pages in length (using the formatting of this thesis). Before extracting the data from the log files into adjacency matrices, they are converted from text files into Excel notebooks which allow for sorting of agent names, event types, and times. This enables a much more efficient transfer of the data.

In order to analyze the data in the long files with social network analysis software, one must create an adjacency matrix for each file. An adjacency matrix possesses an equal number of rows and columns, as both are headed by the same the names of the agents to be studied. In the example below notice that the names in the column headings represent the receivers of the information sent by the names in the first column:

	Alex	Chris	Dale	Francis	Harlan	Jesse	Kim	Leslie	Morgan	Pat	Robin
Alex											
Chris											
Dale											
Francis									1		
Harlan											
Jesse	2	1						2	1		
Kim						1					
Leslie		4	3	2	3				1		
Morgan	1	2				1	2	3		1	1
Pat	3										
Robin	1										

Table 2. Example of Adjacency Matrix

The adjacency matrices are first compiled on and saved in regular Excel notebooks. Every three hundred second time interval receives its own matrix within the session’s Excel notebook. Eight log files result in eight notebooks, but each notebook contains a maximum of thirteen adjacency matrices. In addition to facilitating more rapid error checking, this break down allows researchers to study network development over time. After the Excel notebooks are completed the matrices are individually copied and pasted into new spreadsheets and saved in the comma delimited format required by ORA. Next, the matrices are loaded into ORA so that the matrices from one experimental session are saved together in one meta matrix.

The process of converting these matrices into independent variables begins with use of matrix algebra. ORA makes possible the addition of different matrices, in this case the summation of the thirteen adjacency matrices constructed for each experimental session. The resulting summation is a complete catalog of every interaction that occurred during one experimental session and the record of data from which the independent variables are derived.

Finally, the researcher selects the desired social network measures from the long list provided by ORA and the software calculates the desired measures which are the independent variables. Again, this thesis examines the individual level measures, betweenness, centrality, and closeness, and the group level measure density. Chapter IV details the specific formulas used to calculate the independent variables for each hypothesis.

C. DEFINITION OF HIGH PERFORMANCE

Each hypothesis evaluated in this thesis is statistically compared to a measure of success or performance with the network measures being the independent variables, while the measures of performance being the dependant variables. It is therefore essential to clearly define high performance and describe its constituent dimensions within the ELICIT environment. In order to transpose the results of this thesis and make claims upon the real world, the subsequent descriptions of high performance must be based on legitimate measures.

1. Speed

The first component of success is the time it takes for a player to submit his identification of the terrorist plot. Group performance then becomes the mean submission times of all players participating in the experimental session. For ease of comparison, time scores are normalized to a 0-1 scale, with 1 representing the fastest time to submission. Because all identifications are time stamped in the log files, measurements are easy to construct. In order to compare times meaningfully from one session to another, the clock times of all sessions are considered to be equivalent. In other words, a submission at 2200 seconds after the start of Session 1 is considered to be exactly as fast as a submission at 2200 seconds after the start of Session 2. Each subjects normalized identification time is thus derived from Equation 1, where 3896 represents the maximum time elapsed during experimental sessions:

Equation 1: $T = \frac{3896 - identification\_time}{3896}$

For example, in order to calculate the normalized identification time for a submission occurring at 2200 seconds after the start of *any* experimental session, one substitutes as has been done below:[48]

$$\frac{3896 - 2200}{3896} = .44$$

2. Accuracy

The second component of performance, accuracy, is measured by awarding one point to a correct submission for each part of the identification—who, what, where, and when—and normalizing the score on a 0-1 scale giving equal weight to each part. Thus, a perfectly accurate submission, where all four parts are correct, receives a 1, while a completely inaccurate submission receives a 0. Again, the group performance is the mean accuracy of every participant's identification.[49]

D. STATISICAL ANALYSIS

Once the independent and dependent variables are calculated, the researcher must determine which statistical tests are appropriate for comparing the variables and determining the existence of correlations.

48 Leweling and Nissen, 12th ICCRTS, 10-11.

49 Leweling and Nissen, 12th ICCRTS, 11.

1. Individual-Level Measures

Each Individual–Level hypothesis tests for a correlation between a nodal characteristic (the independent variable) and individual performance (the dependent variable). Using the Kolmogorov-Smirnov test for normality, it is determined with a high degree of certainty that that the independent variables are not normally distributed (i.e., $p< 0.05$ for time, and $p < 0.05$ for accuracy). It is therefore appropriate when testing these hypotheses to use non-parametric tests for correlations, in this case a Kendall's Tau B. Because the hypotheses are directional, i.e. testing whether higher centrality correlates to higher performance, the tests are also one sided.

2. Team-Level Measures

The two Team-Level hypotheses compare the performance of teams. While the data for the Individual-Level Hypotheses are not normally distributed, with the Kolmogorov-Smirnov test for normality it is determined that this data is normally distributed (i.e. $p>.05$) and that it is therefore appropriate when testing these hypotheses to use Pearson’s tests for correlations.

E. SUMMARY

This chapter describes the ELCIT environment, largely borrowing from Leweling and Nissen (2007), and proceeds to outline the techniques used to convert the data recorded during the experiment into reliable measures of centrality and density, the independent variables analyzed in this thesis. Performance, in terms of time and accuracy, are the dependent variables of this thesis. Finally, the independent and dependent variables are checked for correlations. The results of these efforts are described in the subsequent chapter.

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IV. RESULTS AND ANALYSIS

This chapter presents the results and analysis of the hypotheses introduced in Chapter II. It is important for the reader to remember that this thesis examines two different entities: individuals and teams. Section A of this chapter presents the findings of Individual-Level analysis, while Section B covers Team-Level analysis. A discussion of the results occurs in Section C.

A. INDIVIDUAL-LEVEL OF ANALYSIS

Because performance within the ELICIT environment contains two components—time and accuracy—correlations exist sometimes between a nodal characteristic and both time and accuracy, sometimes exclusively time or accuracy, and sometimes neither time nor accuracy.

1. H1.1: Degree Centrality

The first hypothesis is accepted in part, as a correlation exists between an actor's degree centrality and his answer's accuracy. Degree centrality is calculated using the equation below, where *i* and *j* are both actors in a matrix, X, with *n* entities:

Equation 2: $$entity\ i = \frac{1}{2(n-1)} \sum_{i=1}^{n} \sum_{j=1 / i \neq 1}^{n} X(i,j)$$ [50]

Degree centrality and accuracy are correlated ($r = .191$, $p < 0.01$). Using a linear model, degree centrality accounts for

50 Wasserman and Faust, Social Network Analysis, 199.

3.6% of the variance in accuracy. Degree centrality is thus not a useful predictor of accuracy. On the other hand, degree centrality and time to submission do not appear to correlate ($r=.053$, $p> 0.01$). Therefore, it appears that a relationship exists between being positioned in the center of a network and a more accurate answer, but it cannot be said that the relationship is predictive.

2. H1.2: Betweenness Centrality

A correlation exists between the independent variable, betweenness, and an individual's performance, both accuracy and time to submission. The betweenness centrality of entity v in a network is defined as: across all entity pairs that have a shortest path containing v, the percentage that pass through v.[51] The correlation coefficient for betweenness and accuracy is .164 with $p<.01$, while the correlation coefficient for betweenness and time to submission is .113 with $p<.05$. It appears that there is very little common variation between the independent variable and performance-both accuracy and time (4% and 1.2%, respectively), but that a statistically significant relationship exists.

3. H1.3: Closeness Centrality

Like H1.1, an actor's closeness correlates with the accuracy component of performance, but not the time to submission component. An actor's closeness is calculated with the following equations, where G=(V,E) is the graph representation of the square network:

51 Carley, "Measures," ORA Help Manual, Centrality, Betweenness.

Equation 3: $v = \frac{(|V|-1)}{dist}$

Equation 4: $dist = \sum d_G(v,i)$ [52]

For accuracy, r=.154 and p<.05 and for time to submission, r=.013 and p>.05. Again, a relationship exists between the independent variable, closeness, and the dependant variable, accuracy, but that relationship is not predictive.

B. TEAM-LEVEL ANALYSIS

The two subsequent hypotheses test for a correlation between the independent variable, density, and the dependant variables, speed and accuracy.

1. H2.1: Group Density vs. Speed

The most surprising result of this analysis is the correlation between network density and performance. Not only must the null hypothesis be rejected as untenable, but in fact it is determined that a correlation does exist which is exactly opposite of what was assumed; namely that as network density increases time to submission increases as well. One possible explanation for this outcome is that as network density increases actors require more time to process information and manage the larger number of connections to other actors. The Pearson’s correlation between network density and time to submission is -.834 with p=.005.

52 Carley, “Measures,” ORA Help Manual, Centrality, Closeness.

2. H2.2: Group Density vs. Accuracy

From the result of H2.1, it can be inferred that because actors functioning in higher density networks are forced to process an increased amount of information, it takes them more time to submit answers. One might suspect that the additional time and information associated with higher network densities would result in more accurate submissions, but like H2.1, H2.2 must be rejected. There is no statistically significant correlation between network density and the accuracy of answers. The Pearson's correlation between network density and accuracy is .022 with $p=.479$, clearly an ambiguous result, and therefore nothing can be said with certainty. At most, when looking at the scatter plot, one notices a slight upward trend in accuracy as density increases; at least in this case it is in the direction of what had been supposed.

C. DISCUSSION

The three hypotheses dealing with Individual-Level measures have in common the idea of network centrality; that an actor who is central to a network should experience an advantage in terms of performance over actors who are less central. Although in all cases a statistically significant relationship exists between centrality and accuracy, only betweenness centrality exhibits a relationship with speed. Unfortunately, none of the network measures examined in this thesis are useful predictors of an individual's performance. Instead, the Team-Level measure, density, was the only measure found to have predictive value, albeit in the opposite direction of what had been hypothesized. If the explanation for the unexpected result of H2.1 is correct-that as network density increases, on average, actors require more time to submit answers—then it indeed seems plausible that the demand which managing more connections places on actors who are more central to a network lessens some of the advantages gained from that location. That is to say, more central actors, may provide more accurate solutions on account of their position, but that the added demands placed on the position detract from some of its benefits.

Based on these assumptions, it seems that the highest performing individuals should possess a careful balance between a central position and a larger number of links. Although the former may provide better access to information, the latter may tend to overwhelm. Perhaps centrality exhibits a diminishing return; each additional link which makes an actor more central to a network incurs a higher cost—in terms of time and effort—than previously established links. For these conjectures to be true two assumptions must be verified. Firstly, centrality must indeed be a boon to an actor’s information processing capacity—an assertion made by social network analysis literature, but only weakly supported by the results of this thesis. And secondly, an excessive number of links must indeed hinder an actor’s performance—which, in this case, is an intuitive claim concerning human capacity supported by psychology.

As an explanation, this thesis proposes that as network density increases actors require more time to process and respond to incoming information. In as much as central actors possess a greater number of edges (i.e., communication linkages to others), this thesis also argues that centrality in a network has costs, as well as benefits. Further experimentation is needed to test the validity of these conjectures and bring better understanding to Organization Theory, Social Network Analysis, and Information Processing networks.

In sum, the results of this thesis present findings that, though inconclusive, call into question intuition and social network analysis literature. Perhaps, improved techniques and more subtle measures are necessary in order to reconcile predictions with observations. It is clear, however, that the dynamic web of interaction created by the ELICIT experiment involves more complexity than originally had been anticipated; and this added complexity offers future researchers a challenge and the opportunity for greater understanding.

V. IMPLICATIONS FOR THEORIES AND RESEARCH

This chapter begins with discussion of the study's results for Command and Control, Organizational Design, Information Processing, and Social Network Analysis. A brief description of the Edge organization follows and is provided for future researchers who may be interested in analyzing and comparing the rest of the data collected during the ELICIT experiment. Next, opportunities for future research are discussed. Finally, the reader is presented with a brief summery of the thesis's findings and conclusions.

A. IMPLICATIONS FOR MILITARY COMMAND AND CONTROL

Because the ELICIT experiment was modeled to be an intelligence game, the results of this thesis most readily operationalize to units which collect and analyze military intelligence. More generally, however, the results of this thesis seem to reinforce the idea of presenting human beings with a limited and orderly flow of information when designing command and control systems. Rather than encouraging individuals to seek out too much information, command and control systems engineers, by means of their design, ought to prevent the user from becoming burdened with superfluous information.

B. IMPLICATIONS FOR ORGANIZATIONAL DESIGN

It is important to remember that the entities studied in this thesis are individuals, and that human decision making enjoys characteristics and capacities that are far different from those of automated decision making. While human beings seem to have difficulty managing an abundance of links, computers are ever increasingly capable. When it comes to designing the macro-level of features of an organization, the results of this thesis indicate that human capacity must be considered when attempting to maximize performance; human exposure to sources of information should be limited in some fashion. Theorists must be careful not to overemphasize the hierarchies’ stove-pipes while neglecting its ability parcel information into quantities human beings find manageable.

C. IMPLICATIONS FOR INFORMATION PROCESSING THEORY

In as much as the organizations formed during the ELICIT experiment can be seen as information processing units, it would be helpful to understand the difference between information and knowledge processing. The networks in this thesis are created by merging the information networks (factoids) and knowledge networks (postcards). Preliminary results from Leweling and Nissen (2007) indicate that in some situations the sharing of mental models increases the time to submission.[53] Perhaps a better understanding and more meaningful measure would result from separating and analyzing the two networks with similar methods used in this thesis. The effect of centrality in a knowledge network may not be the same as the effect of centrality in an information network.

53 Leweling and Nissen, 12th ICCRTS, 14.

D. IMPLICATIONS FOR USING NETWORK ANALYSIS TO EXPLORE ORGANIZATIONS

Although widely accepted as gauge of an actor's importance to a network, the results of this thesis only weakly suggest that centrality relates to higher performance. A great deal more work must be done in order to truly understand the subtleties and conditions of this property. Centrality seems to confer benefits, but not without costs. The results of the Team-Level hypotheses (H2.1) suggest that there exists an optimal performance density for organizations facing conditions analogous to the one created by the ELICIT experiment. From these results, it can be assumed that a maximally dense network will not exhibit maximum performance. Therefore, it would be advantageous to know if an optimal performance density exists and into what range falls.

E. OPPORTUNITIES FOR FUTURE RESEARCH

It is important to remember that the ELICIT environment provides researchers with the opportunity to experiment in the laboratory with group sizes that have been generally reserved for field studies.[54] ELICIT can be used to examine the effects of a host of different forces which act on organization, including: incentive structure, culture, and the role of planning and strategy. This thesis is limited to a study of the attributes of successful performance in a complex and interdependent information processing

54 H. Kang, H. Yang, and C. Rowley, "Factors in team effectiveness: Cognitive and demographic similarities of software development team members," Human Relations (December, 2006), 1681-1711.

environment, and possible related areas of study abound. For instance, this thesis investigated only the half of the data collected during the ELICIT experiment having to do with the Hierarchy configuration. The other half of the data having to do with the Edge configuration remains unexamined by graph-theoretic techniques. A willing researcher could test exactly the same hypotheses as the ones developed for this thesis and compare the results. In light of the findings having concerning density, a researcher could design an experiment to test for the optimal density levels discussed in Section D of this chapter. The experiment could control for the number of links an actor is allowed to establish during game play by dictating maximums and minimums to different groups of players, which would serve to artificially adjust density and other network measures. Another experiment could be created to study how different organizational forms respond to dynamic situations by changing mission requirements during game play. To add further incite into the role of latent actor traits in network development, an experiment could be conducted which compares nodal characteristics with personality traits.[55] In all, ELICIT is a valuable tool for exploring groups and individuals, and should provide creative researchers with a means to answer complex questions about organizations.

F. SUMMARY

By using of graph-theoretic techniques to compare the information processing behaviors of three groups of mid-level working professionals as each undertakes a series of

55 Borgatti and Foster, Journal of Management Review, 1000.

four complex, interdependent, computer-mediated decision-making exercises, this thesis explores 1) the location within the information processing structure of high-performing individuals v. low-performing individuals, and 2) the exhibited characteristic communication processing patterns of high-performing groups v. low-performing groups. The results of this exploration, though mostly inconclusive, call into question both intuition and social network analysis literature. It is predicted that centrality in a network correlates positively with high performance among individuals; but statistics reveal an almost negligible relationship. It is also hypothesized that high density groups outperform low density groups, but density and performance were found to correlate in exactly the opposite direction: as density increases, performance decreases.

As an explanation, this thesis proposes that as network density increases actors require more time to process information and manage the larger number of connections to other actors. In as much as central actors possess more links than actors on the periphery of a network, this thesis also argues that centrality in a network has costs, as well as benefits, and sometimes the demands of managing too many links can distract an individual from the task at hand. Further experimentation is needed to test the validity of these conjectures and bring better understanding to the fields of Organization Theory and Social Network Analysis.

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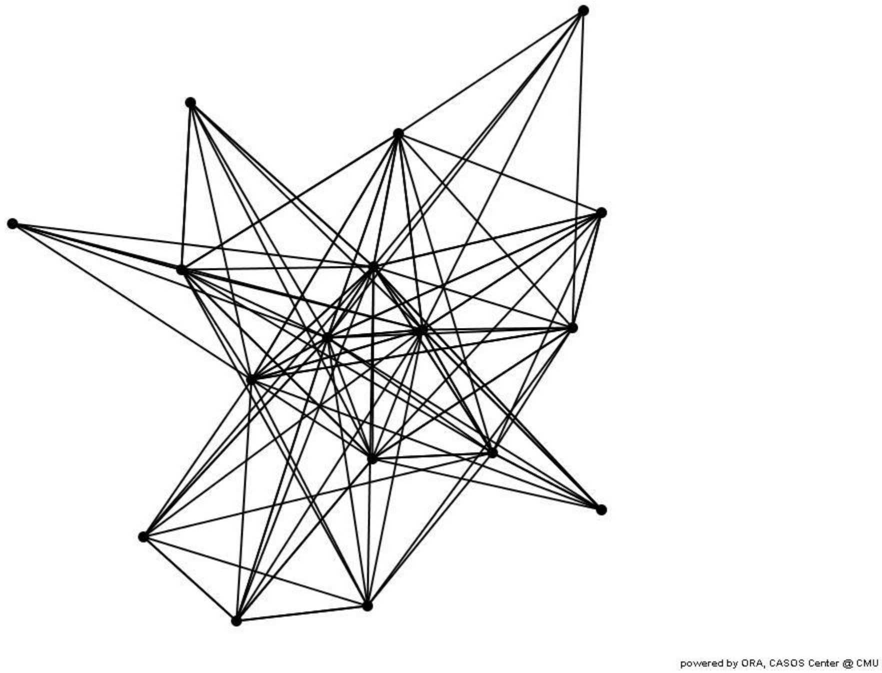
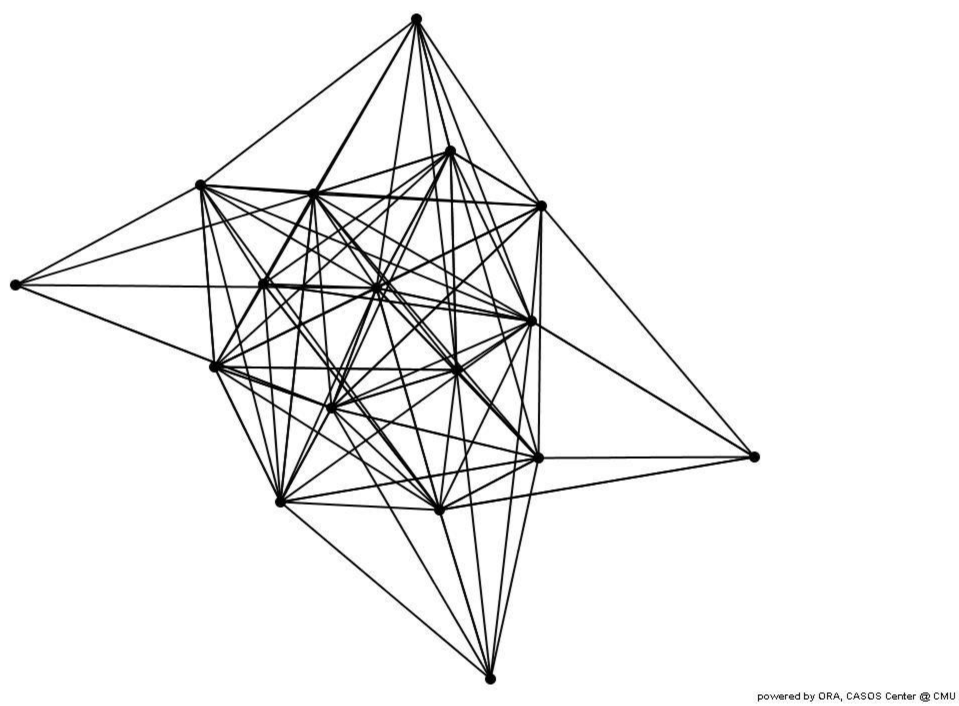
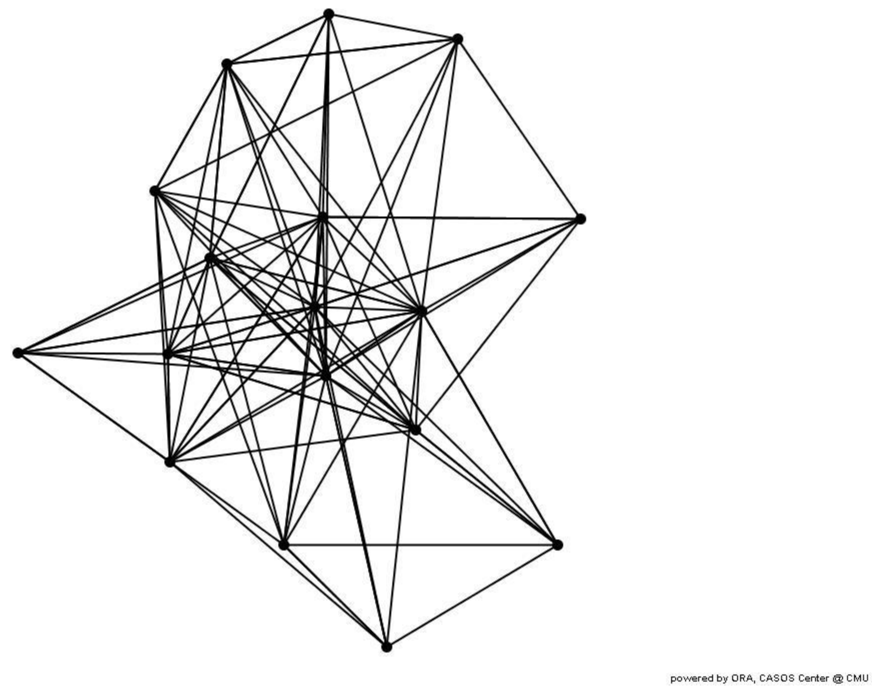
APPENDIX: META MATRICES



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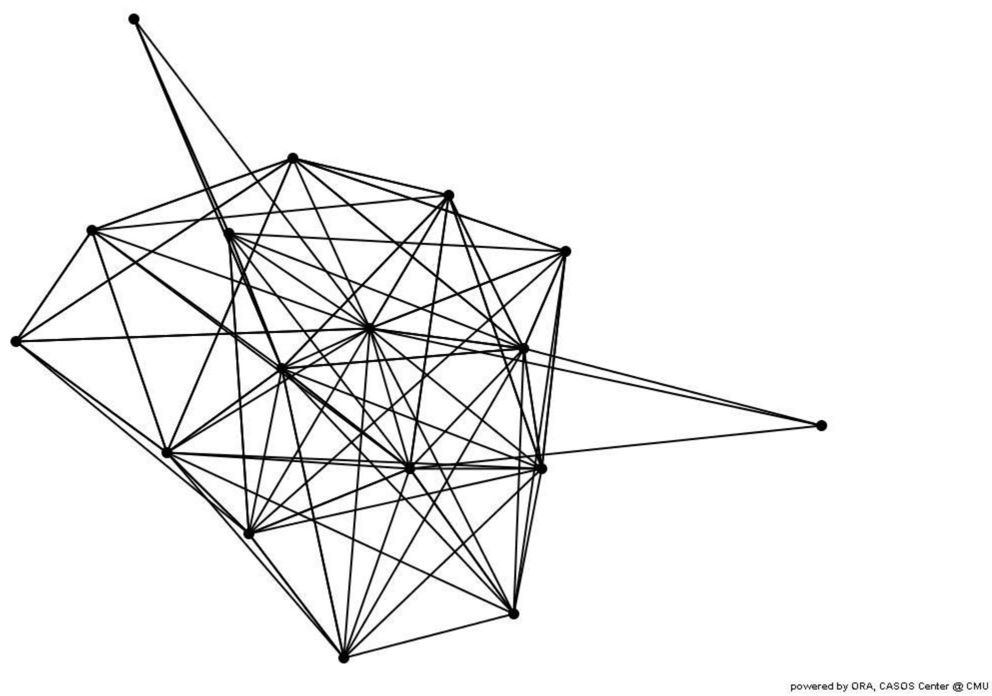
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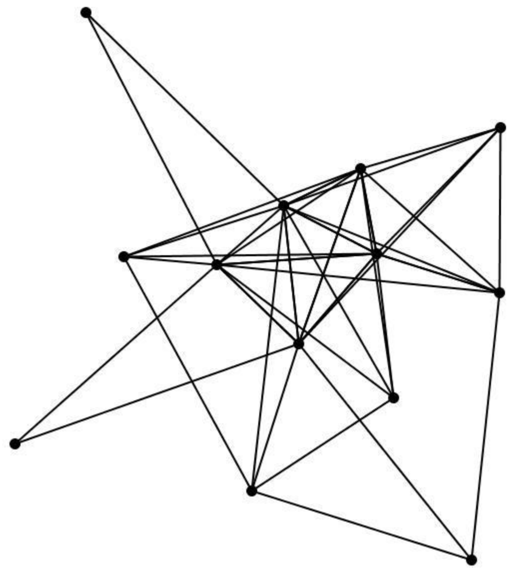

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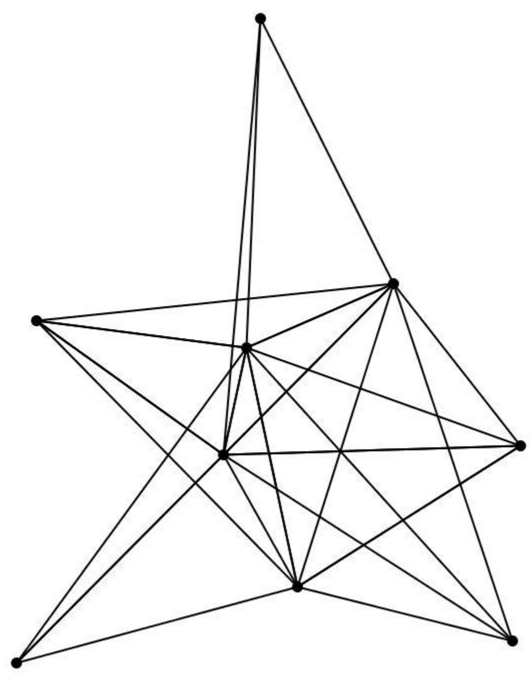

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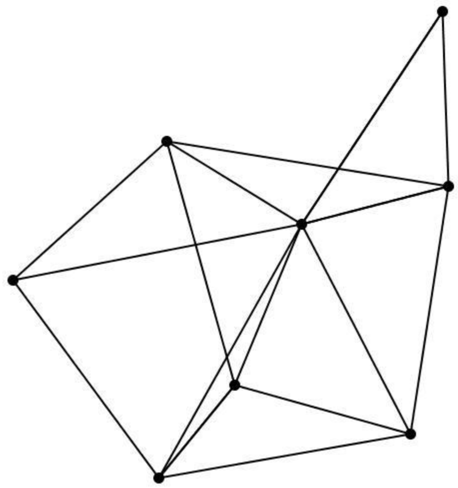

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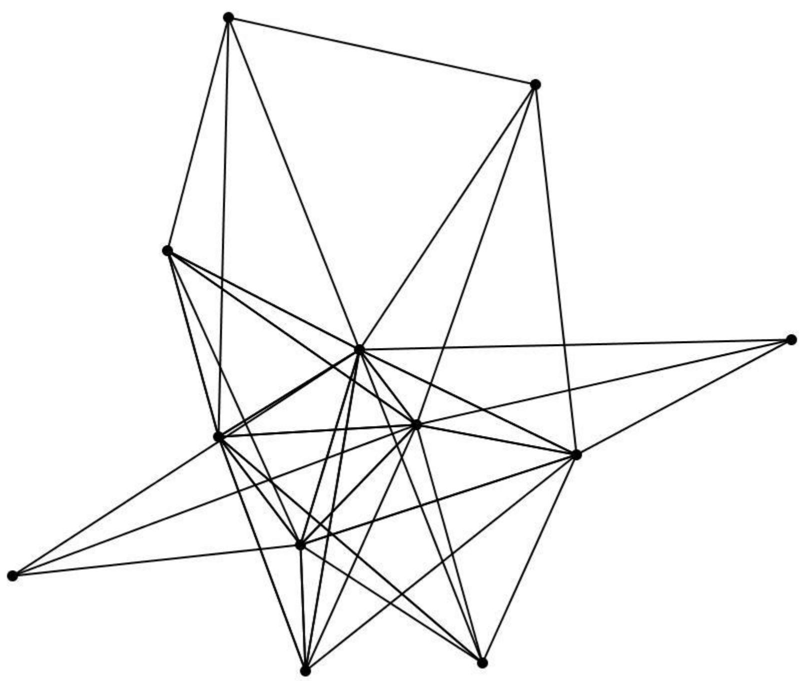

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LIST OF REFERENCES

Alberts, D.S. and R. E. Hayes. *Power to the Edge.* Command and Control Research Project, 2003.

Atkinson, S.R. and James Moffat. *The Agile Organization.* Command and Control Research Project, 2005.

Barnes, J.A. “Graph Theory and Social Network: A Technical Comment on connectedness and connectivity.” *Sociology* 3(2) (1969): 215-232.

Beauchamp, M.A. “An Improved Index of Centrality.” - *Behavioral Science* 10 (1965): 161-163.

Blau, P.M. *Inequality and Heterogeneity*. New York: Free Press, 1977.

Borgatti, S.P. and P.C. Foster. “The Network Paradigm in Organizational Research: A Review and Typology.” *Journal of Management* 29(6) (2003): 991-1013.

Bovasso, Gregory, “A Structural Analysis of the Formation of a Network Organization.” *Group Organization Management* 17(1) (1992): 86-106.

Burt, Ronald S. *Towards a Structural Theory of Action: Network Models of Social Structure, Perception, and Action.* New York: Academic Press. 1982.

Carley, Kathleen M, *ORA: the Organizational Risk Analyzer.* Pittsburgh, Pennsylvania: Carnegie Mellon University, School of Computer Science, Institute for Software Research International, Center for Computational Analysis of Social and Organizational Systems, 2007.

Fombrun, C. and N. Tichy. “Network Analysis in Organizational Settings.” *Human Relations* 32(11) (1979): 923-965.

Friedkin, N.E. “Theoretical Foundations for Centrality Measures.” *American Journal of Sociology* 96(6) (1991): 1478-1504.

Kang, H., H. Yang, and C. Rowley. “Factors in team effectiveness: Cognitive and demographic similarities of software development team members.” *Human Relations* 59(12) (December 2006): 1681-1710.

Leweling, Tara A. and M.E. Nissen. “Hypothesis Testing of Edge Organizations: Laboratory Experimentation using the ELICIT Multiplayer Intelligence Game.” *12th International Command and Control Research and Technology Symposium: Adapting C2 to the 21st Century.* Newport, RI, June, 2007.

Mintzberg, Henry. *Structures in Fives: Designing Effective Organizations.* Upper Saddle River, New Jersey: Prentice Hall, 1983.

Monge, P. R. and N.S. Contractor. *Theories of Communication Networks.* Oxford: Oxford University Press, 2003.

Pearce, J.A. and F.R. David. “A Social Network Approach to Organizational Design-Performance,” *Academy of Management Review* 8(3) (July 1983): 436-444.

Podolny, J. M. and K. Page. “Network Forms of Organization.” *Annual Review of Sociology* 24 (1998):57-76.

Tushman and Nadler, “Information Processing as an Integrating Concept in Organizational.” *The Academy of Management Review* 3(3) (July 1978): 613-624.

Wasserman, Stanley and Katherine Faust. *Social Network Analysis: Methods and Applications.* New York: Cambridge University Press, 1994, 179.

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